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(54) Title: A PROCESS FOR REMOVING ESSENTIALLY NAPHTHENIC ACIDS FROM A HYDROCARBON OIL			
(57) Abstract			
<p>A process for removing essentially naphthenic acids from a crude oil which has not previously been fractionated by distillation, or from which only a naphtha fraction has been distilled. The crude oil is hydrogenated at 1-50 bars and 100-300 °C over a catalyst of the kind used for hydrogenation of atmospheric residue oils. As a catalyst, especially Ni-Mo or Ni-Co deposited on alumina as a carrier material is used.</p>			

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A process for removing essentially naphthenic acids  
from a hydrocarbon oil.

The present invention relates to a process for removing essentially naphthenic acids from a hydrocarbon oil, more specifically from a crude oil which has not previously been distilled into fractions, or from a crude oil in which only a naphtha fraction has been distilled.

It is well known that crude oil and crude oil fractions contain sulphur compounds, nitrogen compounds and other undesired compounds, and a large number of processes have been proposed for removing such compounds from crude oil fractions. Catalytic hydrogenation is a very commonly used method for removing i.a. sulphur and nitrogen content. Such hydrogenations of naphtha fractions are typically carried out at pressures of e.g. 10 to 30 bars and temperatures of 250 to 350 °C, whereas corresponding treatments of distillates are carried out at pressures of 20 to 80 bars and temperatures of 270 °C to 400 °C, and treatments of residue oils are carried out at pressures of 100 to 150 bars and temperatures of 300 °C to 450 °C. Such hydrogenation treatments also remove any naphthenic acids contained in the hydrocarbon fraction. The term naphthenic acids is used herein as a common designation for naphthenic, aromatic and paraffinic carboxylic acids.

It may often be strongly desired to remove particularly naphthenic acids from hydrocarbon oils, because they have a strong corrosive action on the process equipment. For that reason it would be desirable to eliminate the naphthenic acids as early as possible in the oil refining process.

It is has now been discovered that it is possible to carry out such removal of the naphthenic acids from a non-fractioned or only topped crude oil by a selective hydrogenation of the naphthenic acids under very mild conditions. Under such mild conditions, any substantial amount of desulphuration reactions, denitrification reactions and reactions leading to saturation of aromatics, is avoided, which results in a mode-

rate hydrogen consumption.

Thus, the invention provides a process for removing essentially naphthenic acids from a hydrocarbon oil, in which process the hydrocarbon oil is hydrogenated at an elevated temperature over a catalyst of the kind used for hydrogenation of atmospheric residue oils, preferably a catalyst consisting of nickel-molybdenum or cobalt-molybdenum, deposited on alumina as a carrier material. The process is characterized by there  
10 being used as hydrocarbon oil:

(a) a crude oil which has not previously been distilled into fractions, or

(b) a crude oil from which a naphtha fraction has been distilled,

15 and by the hydrogenation being carried out at 1 to 50 bars and 100 °C to 300 °C.

In both embodiments of the process of the invention it is preferred to carry out the hydrogenation at 20 to 30 bars and at  
20 a temperature of 200 °C to 250 °C.

The hydrogenation is suitably effected in one or more parallel reactors having a fixed catalyst bed. As mentioned, the catalysts utilized in the process of the invention are such catalysts which have proved to be suitable for hydrogenation of  
25 atmospheric residue oils. It is important for a successful carrying out of the process that the carrier material of the catalyst is sufficiently porous to allow penetration of even the heaviest part of the crude oil into the catalyst pores.  
30 Therefore, the carrier material should have a porosity such that the final supported catalyst preferably has a porosity of the magnitude 10 to 12 nanometers (nm). Particularly useful catalysts comprise nickel-molybdenum or cobalt-molybdenum deposited on alumina as a carrier material. The oil flow  
35 through the catalyst is preferably 0.5 to 5.0 m<sup>3</sup> oil per m<sup>3</sup> catalyst per hour, most preferred 1.0 to 3.0 m<sup>3</sup> oil per m<sup>3</sup> catalyst per hour.

As a pretreatment of the crude oil it may be advantageous to carry out a conventional desalting of the crude oil with water.

- 5 The process of the invention allows a selective reduction of the content of naphthenic acids in the crude oil to less than about 5 to 6%, without simultaneous hydrogenation of sulphur compounds and nitrogen compounds which may be present. Con-
- 10 currently with a strong reduction of the content of naphthenic acids, a certain reduction of the metal content in the crude oil also takes place. This is no disadvantage; especially not if the hydrogenated crude oil is to be processed for example in a catalytic cracker, because the catalyst utilized in the hydrogenation process has a much higher metal tolerance than
- 15 the catalyst employed in a cracking process. Therefore, if the crude oil is to be subjected to cracking, it may be advantageous to carry out the process of the invention at a temperature which is sufficiently high to achieve even a substantial reduction of the metal content, even though such higher tempe-
- 20 rature would result in a stronger reduction of the sulphur and nitrogen content and consequently in an increased hydrogen consumption, and possibly would necessitate sulphur recovery and nitrogen removal.
- 25 The process of the invention may easily be included as a part of a crude oil refining process for refining acid crude oils. Upon a desalting of the crude oil and heating thereof by heat exchange to 100 - 300 °C, preferably to 230 - 250 °C, the crude oil may be passed through a hydrogenation reactor system
- 30 for implementation of the process of the invention, whereupon it is passed to the next heat exchangers in the refining process and then to the crude oil boiler and the distillation column. The effective but lenient hydrogenation of essentially naphthenic acids achieved by the process of the invention will
- 35 delimit the consumption of hydrogen in a crude oil refining process and consequently reduce the costs for hydrogenation reactors compared to previously known and more strict hydrogenation treatments of the crude oil. The costs of integrating the process of the invention with the refining process will

amount to only a small fraction of the costs of a traditional complete pretreatment plant. Thus, with the new process incorporated into a crude oil refining process, there will be no need for any additional desalters, heat exchangers and  
5 strippers or any additional capacity for waste water treatment.

An example on an embodiment of the process of the invention is described in more detail hereinbelow. The main features of  
10 this embodiment are shown in the appended drawing.

Crude oil from a crude oil stock is heated to 100-150 °C and fresh water is added thereto. The mixture of water and crude oil is pumped to a desalter wherein the mixture is separated  
15 into oil and water by gravity and by application of an electrical field. Salt-containing water containing also a minor amount of hydrocarbons is passed to a water purification plant and the desalted crude oil is passed to a prefractionation unit. In the prefractionation unit, the lightest part of the  
20 oil, e.g. about 15%, is separated out, which part consists of a naphtha fraction having a boiling temperature of up to 100-200 °C. Such prefractionation is not strictly required but is preferably effected to improve the operation conditions of the subsequent hydrogenation, because it reduces the hydrocarbon  
25 partial pressure as well as the total volumetric flow through the hydrogenation plant.

The bottom fraction from the prefractionation unit is pumped to the hydrogenation unit wherein it is first mixed with a hydrogen-rich recycle gas from said hydrogenation unit and  
30 with fresh make-up hydrogen gas from a hydrogen plant, which may be a plant for steam prereforming of natural gas, LPG or naphtha. The mixed feed is fed to e.g. five parallel reactors, each having a fixed catalyst bed containing a catalyst consisting of Ni-Mo on  $Al_2O_3$ . Upon contact with the catalyst, the  
35 carboxyl groups in the crude oil, and particularly the carboxyl groups of the naphthenic acids, react with hydrogen with formation of water. The effluent from the hydrogenation reactors are passed to a high pressure separator. The liquid product from the high pressure separator is passed to a low

pressure separator, while the gas from the high pressure separator is recycled to the feed as indicated above. If necessary, the gas which is separated out in the low pressure separator is passed to a sulphur recovery plant, together with a  
5 purge stream taken from the above-mentioned recycle gas. The crude oil from the low pressure separator is passed to a stripper wherein the lightest hydrocarbons and any  $H_2S$  are stripped off. If necessary, even this gas stream is passed to the sulphur recovery plant. The treated crude oil which is  
10 withdrawn from the stripper is mixed with the top fraction which was separated from the crude oil in the prefractionation unit prior to the hydrogenation, and the resulting mixture is passed to a storage tank for neutralized oil.

15 Suitable process equipment and suitable procedures for carrying out the process of the invention will be essentially similar to those utilized in well known processes for hydrogenation of gas oils, except that equipment in connection with sulphur recovery and nitrogen removal will often not be  
20 required for the present process. Persons skilled in the art will easily be able to accommodate known gas oil hydrogenation techniques to the process of the invention.

The invention is shown in more detail in the following examples.  
25

#### Example 1

In a pilot plant for hydrogenation processes comprising a reactor charged with 500 ml of catalyst in a fixed bed, hydrogenation of 0.5 l/h of crude oil was carried out in several  
30 runs at a pressure of 20 bars and at temperatures of 230 °C, 250 °C, 300 °C and 350 °C, respectively. The catalyst was Ni-Mo on  $Al_2O_3$ , having a pore size of 10-12 nanometers. 200 Nl  $H_2$  per liter of oil was used and the oil flow through the catalyst was 1.0 liter of oil per liter of catalyst per hour. The  
35 untreated crude oil has the following characteristics:

Acid number, mg KOH/g oil	2.6
Metal content, ppm	10
Sulphur content, ppm	4572
Nitrogen content, ppm	541

The results obtained with respect to the reduction of the acid number are given in Table 1 below, which also gives the metal content, the sulphur content and the nitrogen content of the hydrogenated crude oil product.

Table 1

Temp. °C	Acid number mg KOH/g	Metal content ppm	Sulphur content ppm	Nitrogen content ppm
230	0.15	7.5	4572	542
250	0.07	5.5	4334	525
300	0.06	4.2	3019	510
350	0.15	2.9	1452	506

The test results show that it is possible at 230 °C and 20 bars to selectively hydrogenate the naphthenic acids in the crude oil from a content corresponding to an acid number of 2.6 mg KOH/g oil to a content as low as 0.15 mg KOH/g oil. The sulphur compounds and nitrogen compounds in the crude oil were not hydrogenated to any measurable extent and it may be presumed, therefore that the hydrogenation may be performed at a commercial scale without any need for sulphur recovery and nitrogen removal. Concurrently with a strong reduction of the acid number, even a certain reduction of the metal content of the crude oil occurred at 230 °C, viz. a reduction from 10 ppm to 7.5 ppm. This represents no disadvantage, particularly not if the hydrogenated crude oil is to be processed for example in a catalytic cracker, because the catalyst utilized in the hydrogenation process has a much higher metal tolerance than the catalyst used in a cracking process.



Even at the higher temperatures, 250 °C, 300 °C and 350 °C, a very satisfactory reduction of the acid number is also achieved, together with an increasing reduction of the metal content. However, with increasing temperature an increasing  
5 hydrogenation of the sulphur compounds and the nitrogen compounds is also taking place. This brings about an increased hydrogen consumption and necessitates sulphur recovery and nitrogen removal, which most often is not desired in connection with the process of the invention.

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Tests carried out with the above described untreated crude oil at 230 °C, at the above defined conditions, have shown that the catalyst stability, expressed as the total acid number in mg KOH/g, remained approximately constant for a long period of  
15 time at a catalyst performance which was satisfactory for commercial operation. The results are given in Table 2 below.

Table 2  
Catalyst stability at 230 °C

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	Days in operation	Total acid number (mg KOH/g)
	1	0.1
	10	0.2
	40	0.2
25	60	0.2
	95	0.2

A reduction of the acid number of the crude oil to a value lower than 0.5 mg KOH/g is considered sufficient to fulfil the  
30 aim of the invention.

#### Example 2

Tests were carried out under the same conditions as in Example 1, except that the operation pressure was increased to 50  
35 bars.

The results obtained with respect to the reduction of the acid number are given in Table 3 below, which table also gives the metal content, the sulphur content and the nitrogen content of

the hydrogenated crude oil product.

Table 3

5	Temp. °C	Acid number mg KOH/g	Metal content ppm	Sulphur content ppm	Nitrogen content ppm
	230	0.15	7.8	4468	558
	250	0.07	5.9	4270	539
10	300	0.06	3.1	3102	524
	350	0.39	1.3	1176	481

Even when the crude oil is hydrogenated at 50 bars, a strong reduction of the acid number is achieved at 230 °C, with a concurrent reduction of the metal content from 10 ppm to 7.8 ppm. The tendency of the results at increasing temperature is approximately the same as for the hydrogenation at 20 bars in Example 1.

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Patent claims

1. Process for removing essentially naphthenic acids  
5 from a hydrocarbon oil, in which process the hydrocarbon oil is hydrogenated at an elevated temperature over a catalyst of the kind used for hydrogenation of atmospheric residue oils, preferably a catalyst consisting of nickel-molybdenum or cobalt-molybdenum deposited on alumina as a carrier material,  
10 characterized by there being used as hydrocarbon oil:  
    (a) a crude oil which has not previously been distilled into fractions, or  
    (b) a crude oil from which a naphtha fraction has been distilled,  
15 and by the hydrogenation being carried out at 1 to 50 bars and 100 °C to 300 °C.
2. A process according to claim 1, characterized in that the hydrogenation is carried out at 20-30 bars and 200-250 °C.  
20
3. A process according to claim 1 or 2, characterized by there being used a catalyst having a porosity in the range of 10 to 12 nanometers (nm).
- 25 4. A process according to any of claims 1 to 3, characterized in that the crude oil is fed at a flow rate of 0.5-5.0 m<sup>3</sup> of oil per m<sup>3</sup> of catalyst per hour.
5. A process according to claim 4, characterized in that  
30 the crude oil is introduced at a flow rate of 1.0-3.0 m<sup>3</sup> of oil per m<sup>3</sup> of catalyst per hour.
6. A process according to any of claims 1 to 5, characterized by there being used a crude oil which has previously  
35 been desalted.
7. A process according to any of claims 1 to 6, characterized in that it is carried out in one or more reactors having a fixed catalyst bed.

8. A process according to any of claims 1 to 7, characterized by there being used a crude oil which is to be subjected to a refining process, and which has been desalted and heated to 100-300 °C, preferably to 230-250 °C, and by the  
5 hydrogenated crude oil being recycled to the refining process for further heating and feeding into the distillation column.

9. A process according to any of claims 1 to 8, characterized by there being used a crude oil from which a naphtha  
10 fraction has been distilled, and by the hydrogenated crude oil being mixed with said distilled naphtha fraction.

10. A process according to any of claims 1 to 9, characterized in that the hydrogenation is carried out at a temperature sufficiently high to reduce to a substantial extent even  
15 the metal content and the sulphur content of the crude oil.

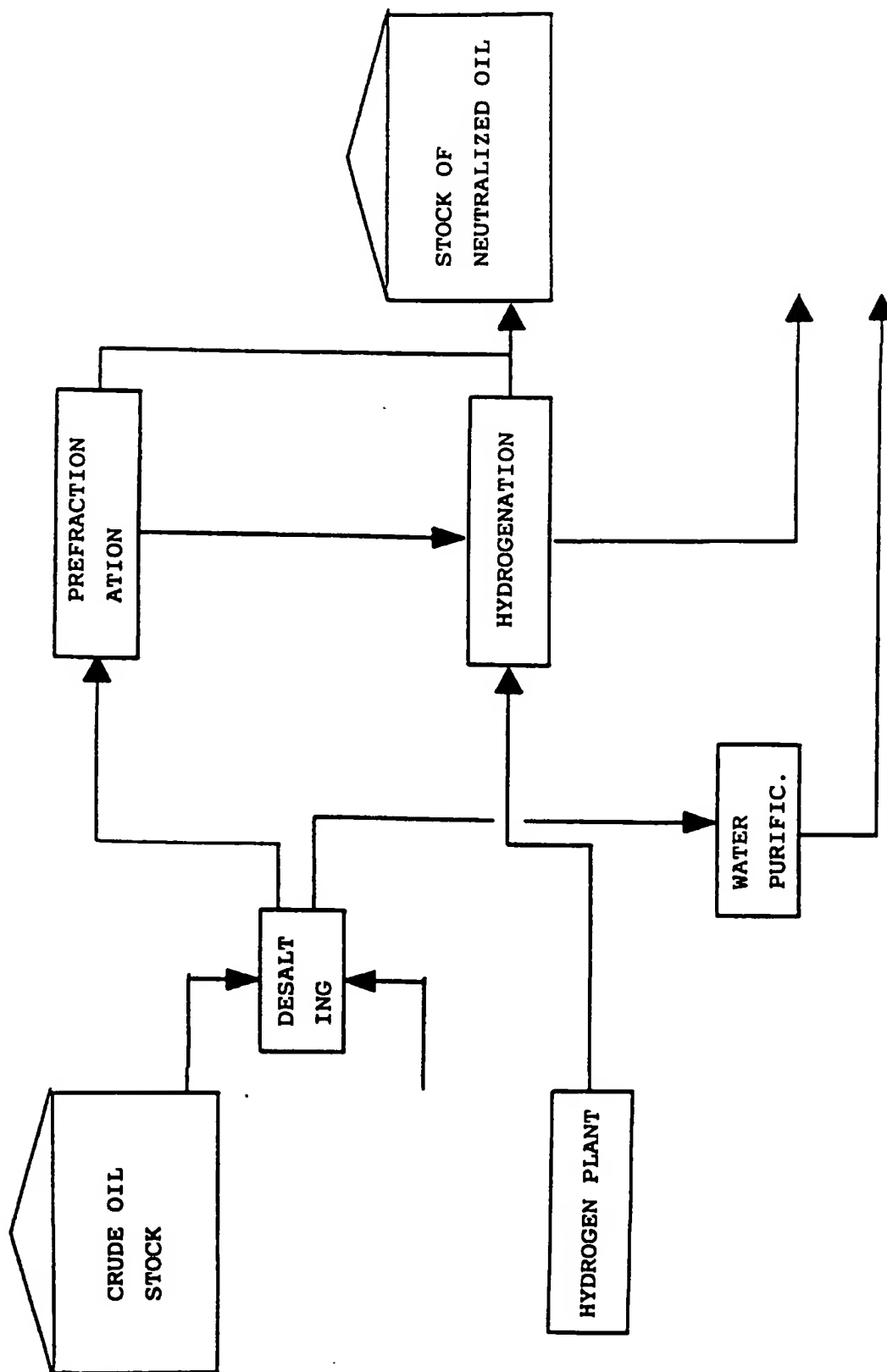
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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO 95/00142

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C10G 45/50, C10G 35/04

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: C10G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2734019 A (JAMES R. MILLER ET AL), 7 February 1956 (07.02.56)  --	1-10
X	US 3876532 A (ROBERT A. PLUNDO ET AL), 8 April 1975 (08.04.75), see especially column 4 and 5  --	1-10
X	EP 0208361 A2 (SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V.), 14 January 1987 (14.01.87)  --	1-10
A	US 3488716 A (JACKSON ENG ET AL), 6 January 1970 (06.01.70)  -- -----	1-10

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

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Information on patent family members

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Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US-A-	2734019	07/02/56	NONE		
US-A-	3876532	08/04/75	NONE		
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